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Specification and Drawings, as originally filed, with Application for Patent Serial No: **2,314,405**, on July 24, 2000, by **CATENA NETWORKS CANADA INC.**, assignee of Alberto Ginesi, for "An Improved 8 Bits/Symbol Messaging Scheme for G.LITE.BIS and G.DMT.BIS".

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AN IMPROVED 8 BITS/SYMBOL MESSAGING SCHEME FOR G.LITE.BIS AND G.DMT.BIS

ABSTRACT

It has been pointed out that the initialization sequence contains many elements that are limiting loop coverage. One of these is the reliability of the protocol used for messages during the Exchange phase of initialization (NG-084). In particular, the fact that the indexes of the carrier used for exchanging the messages are fixed is the main performance limiting factor. Here, we propose to make these indexes adaptive according to the frequency distribution of the channel SNR. This is known as the Exchange phase takes place after Channel Analysis, so that both transceiver can select the best 4 carriers (with the best SNR) to be used for the messages. The indexes of the 4 carriers can be exchanged using the reliable 1 bit/DMT symbol modulation.

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1. Introduction:

The existing G.992.2 and G.992.1 Standards (both of which are incorporated herein by reference) use an 8 bits per DMT symbol modulation based on two fixed set of four carriers in order to exchange the following messages:

D/S

- C-RATES-RA/C-CRC RA1/C-MSG –RA/C-CRC-RA2: 130 DMT symbols = 960 bits (C-RATES-RA)+ 16 bits (C-CRC-RA1) + 48 bits (C-MSG-RA) + 16 bits (C-CRC-RA2);
- C-MSG 2/C-CRC3 /C-RATES2/C-CRC4/: 9 DMT symbols = 32 bits (C-MSG2) + 16 bits (C-CRC3) + 8 bits (C-RATES2) + 16 bits (C-CRC4)
- C-B&G/C-CRC5: 64 DMT symbols = 496 bits (C-B&G) + 16 bits (C-CRC5)

U/S

- R-RATES-RA/R-CRC RA2/R-MSG –RA/R-CRC-RA1: 15 DMT symbols = 8 bits (R-RATES-RA) + 16 bits (R-CRC-RA2) + 80 bits (R-MSG-RA) + 16 bits (R-CRC-RA1)
- R-MSG 2/R-CRC3 /R-RATES2/R-CRC4: 9 DMT symbols = 32 bits (R-MSG2) + 16 bits (R-CRC3) + 8 bits (R-RATES2) + 16 bits (R-CRC4)
- R-B&G/R-CRC5: 512 DMT symbols = 4080 bits (R-B&G) + 16 bits (R-CRC5)

Four (4) carriers are used to modulate the bits of these messages, each carrier being loaded with 2 bits (QPSK modulation). The same bits are also modulated into a set of back-up carriers for improving robustness. The following sets are used by G.992.1 Annex A and G.992.2.

D/S: Primary set: index # 43,44,45,45 – backup: index # 91, 92, 93, 94

U/S: Primary set: index # 10,11,12,13 – backup: index # 20, 21, 22, 23

The receiver can optimally combine the bits carried in the two set of carriers in order to improve reliability. However, on long loops, especially for the D/S tones, the backup set of tones is useless as the SNR in that frequency band is much lower than the one in the frequency band of the primary carriers. In this cases the BER (Bit Error rate) is determined by the SNR on the primary set. Within a set, the highest BER within the four carriers, determine the overall bit error rate on the message (see equation (2) below). As a result, increasing the number of set of carriers has limited benefits, as that still does not guarantee best performance, and it would further complicate the messaging protocol.

As is well known, the BER for QPSK modulation is

$$BER_i = Q(\sqrt{SNR_i}) \qquad (1)$$

and the overall BER over the 4 carriers (i.e. the average BER for the decoded message) is

$$BER = \frac{1}{4}\sum_{i=1}^{4} BER_i \qquad (2)$$

The MER (Message Error Rate) for a given message of L bits is then

$$MER = 1 - (1 - BER)^L \qquad (3)$$

With regard to the initialization messages, L is the number of bits of the message the CRC bytes are computed from. As the MER increases with L, one should consider the max value

of L. Lmax for the initialization messages, when evaluating the reliability of the messaging scheme. For D/S Lmax = 960 (C-RATES-RA) while for U/S Lmax = 4080 (R-B&G).

For example, in order to have MER<10-2, from (3) we get

D/S (L_{max}=960) $BER < 10^{-5}$

U/S (L_{max}=4080) $BER < 2.5 \cdot 10^{-6}$

In terms of the required SNR in the carriers, that means the U/S messages require only a fraction of a dB higher SNR to compensate for the longer message. Given that, and the fact the D/S usually experiences poorer per-channel SNRs, in the following we concentrate on D/S.

2. Proposed 8 bits per symbol messaging scheme

The present invention keeps the basic modulation format for the 8 bit messaging scheme, that is the scheme is still based on the use of 4 carriers over which to modulate 4 QPSK symbols. However, we make the indexes of the 4 carriers adaptive, according to the estimated line SNR. The indexes of the 4 carriers are selected by the receiver to correspond to the sub-channels with the best SNRs. The SNR estimate is available at that time during initialization as the 8 bits/symbol messaging scheme takes place after C/R-MEDLEY. The set of 4 indexes is then exchanged between the two ATUs by using the more reliable 1 bit per symbol messaging. As a result of the improve reliability of the selected set of carriers, just one set of carriers needs to be used.

Figure 1 illustrates the part of the G.992.1 and G.992.2 initialization sequence that we propose to change in order to accommodate for the exchange of the indexes of the carriers.

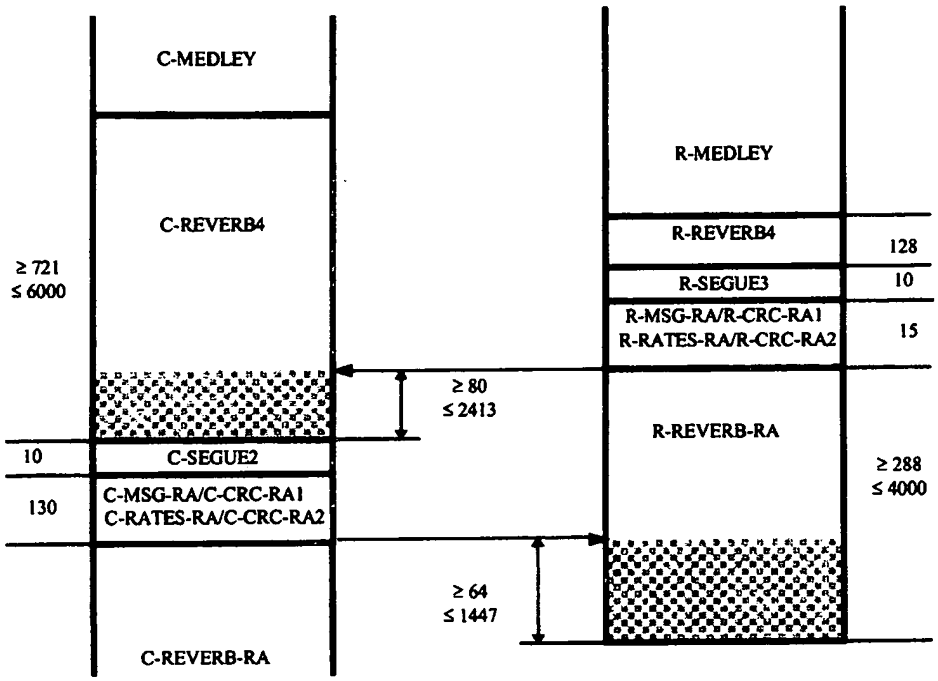


Figure 1 – Part of the current EXCHANGE phase of Initialization

Figure 2 shows the required changes.

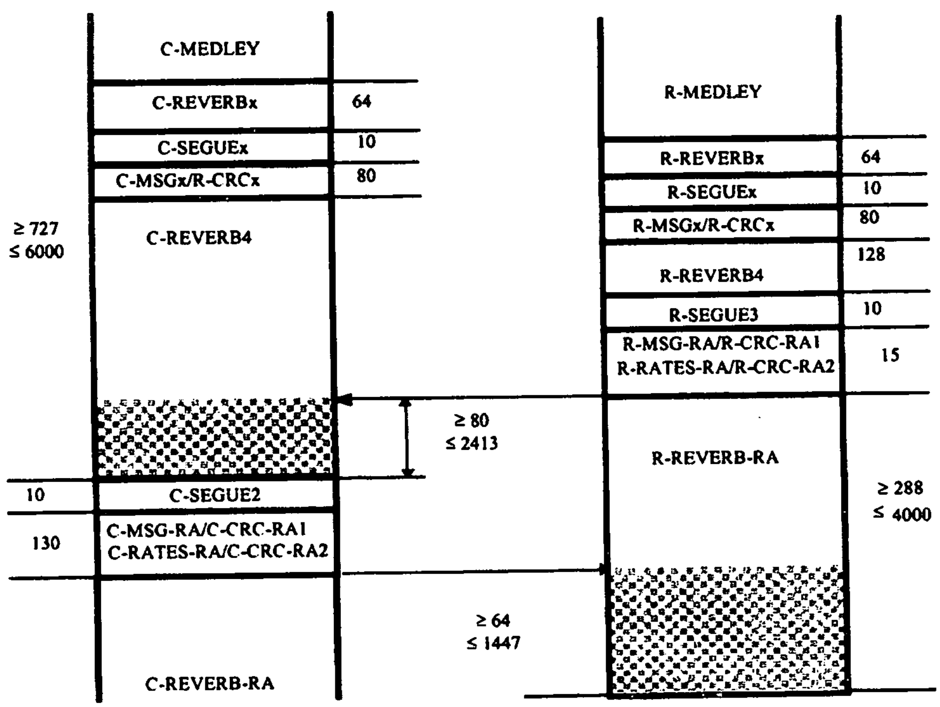


Figure 2 – Proposed changes to the EXCHANGE phase of Initialization

The format of R-MSGx and C-MSGx is shown below:

	Prefix	Carrier index #1	Carriers index #2	Carriers index #3	Carriers index #4
Number of bytes	4	1	1	1	1

The Prefix is a 4 byte prefix of {01010101 01010101 01010101 01010101_2}. The other fields contain the 4 carrier indexes with the best SNR in decreasing order (SNR (carrier index #1) > or = SNR (carrier index #2) > or = SNR (carrier index #3) > or = SNR (carrier index #4)), represented in bit format: the byte corresponding to carrier index #n is the binary representation of that index.

The message is followed by a 16 bits CRC that shall be transmitted with the same modulation format (1 bit/symbol modulation). A total of 80 DMT symbols are then required to transmit the 80 bits C/R-MSGx/C/R-CRCx message

3. Performance of the new messaging scheme

Figure 3 shows the performance of the proposed messaging scheme compared to the current one, in terms of MER of C-RATES-RA . The two plots refer to two different cross-talk scenarios. The one on the left is with 24 ADSL NEXT&FEXT, the one on the right is with 24 DSL NEXT. Loop lengths are selected in order to allow for a non zero net throughput in presence of a coding scheme. In particular, when Reed Solomon (RS) FEC only is used, a non zero throughput is guaranteed for the17 kft and 18 kft loops in both plots. When Trellis + RS is used, reach an be extended to 19 kft with 24 ADSL NEXT&FEXT (plot on the left) and to 20 kft with 24 ADSL NEXT (plot on the right).

A seen, in these conditions the current standard messaging scheme is completely inadequate as the MER approaches 1 for these loops. That means that even though the channel would allow a non zero net data rate, the non reliability of the 8 bits per symbol messages would not allow to activate the link. The proposed scheme instead is sufficiently reliable in all of these cases.

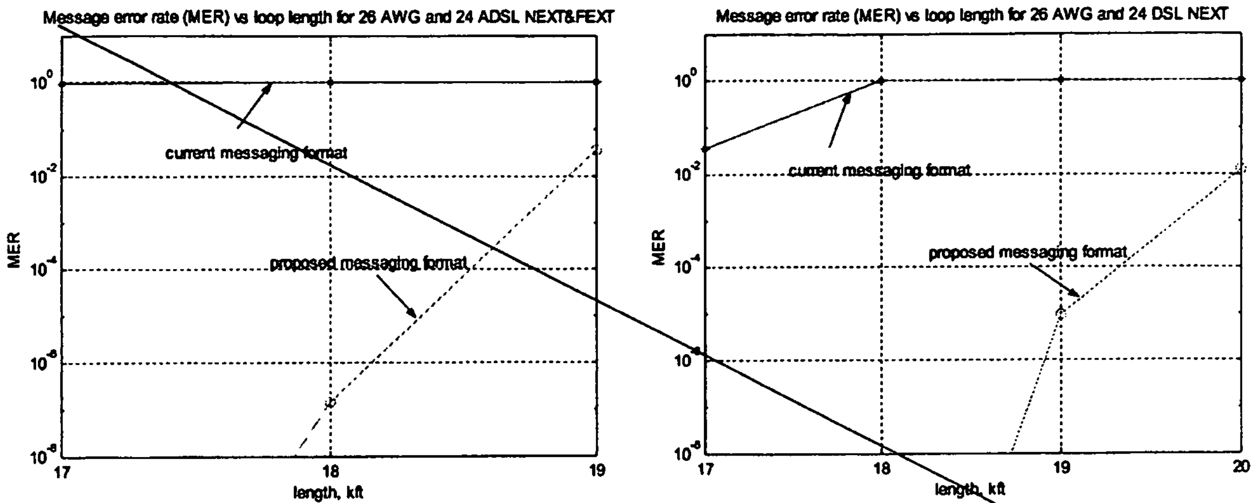


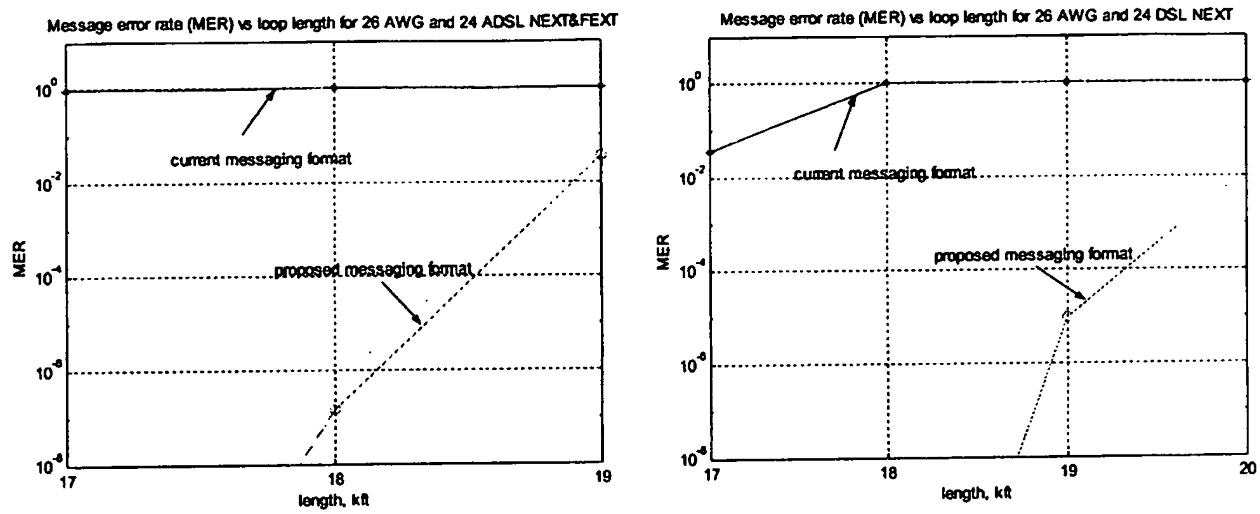
Figure 3 – Performance comparison between the proposed scheme and the current one in terms of Message Error rate

References

NG-084 (incorporated herein by reference) "G.lite-bis: Loop coverage and initialisation procedures." AMD, PairGain, Ameritech, 3COM, Matsushita, Aware, Centillium, Motorola, Nuremberg meeting, 2-6 August 1999.

Summary

1. The modulation method for xMSG-2 should be based on the method proposed in this contribution



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